Design, Fabrication, and Analysis of a Utility Strip for Light Utility Trucks

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2014 ASM

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TITLE: Design, Construction and Evaluation of a Utility Strip for a Light Utility Truck

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DATE SUBMITTED: June 3, 2014

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Secondly, I would like to thank my parents and family for their support throughout my college career.

ABSTRACT

This senior project discusses the design and fabrication of a utility strip for a light utility truck. The utility strip is desirable for off road enthusiasts with its double use as a dirt bike ramp as well as a traction strip. This report will show the cost of materials as well as labor, and if it is feasible for mass production.

Tests were conducted which indicated that the Utility Strip was able to support the weight of a dirt bike as a ramp, as well as regain traction to a two-wheel drive truck stuck in the sand. This product can be put on the market to appeal to off-road enthusiasts.

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INTRODUCTION

Two-wheel drive trucks transport dirt bikes while off-road. If the terrain is soft or slippery, these trucks have a high chance of getting stuck and losing traction. This happens more times than other off the main road where no traffic likely passes by. A winch is sometimes attached to the bumper of trucks in order to pull the truck out. If there is no winch point or other vehicle to pull the stuck truck out, then the truck will remain stuck without traction.

There are traction strips on the market for these situations to wedge under the wheel to regain traction. While the higher end traction strips are expensive and have a low utility use, there needs to be a approach to make these more versatile. If there were a traction strip on the market that could also be used as a ramp for loading and unloading a dirt bike from the bed of a truck, then purchasing one of these strips would be much more desirable for customers.

This project will show the design and construction of a utility strip that has the strength of a dirt bike ramp as well as the flexibility and grip of a traction strip to appeal to the off road enthusiast.

LITERATURE REVIEW

Research was done to gather information on existing designs of folding motorcycle ramps as well as folding vehicle traction devices.

Jerry P Lensing's design of a Tri-Folding Ramp (shown in Figure 1) is a portable, collapsible device that includes three sections, which define an upper surface of the ramp as having an arc-shaped profile. The arc-shaped profile of the ramp can reduce the loading angle between the distal end of the ramp and the upper loading surface, thereby inhibiting contact between the vehicle's undercarriage and the ramp's upper surface and/or the upper loading surface as the vehicle is entering or exiting the ramp.

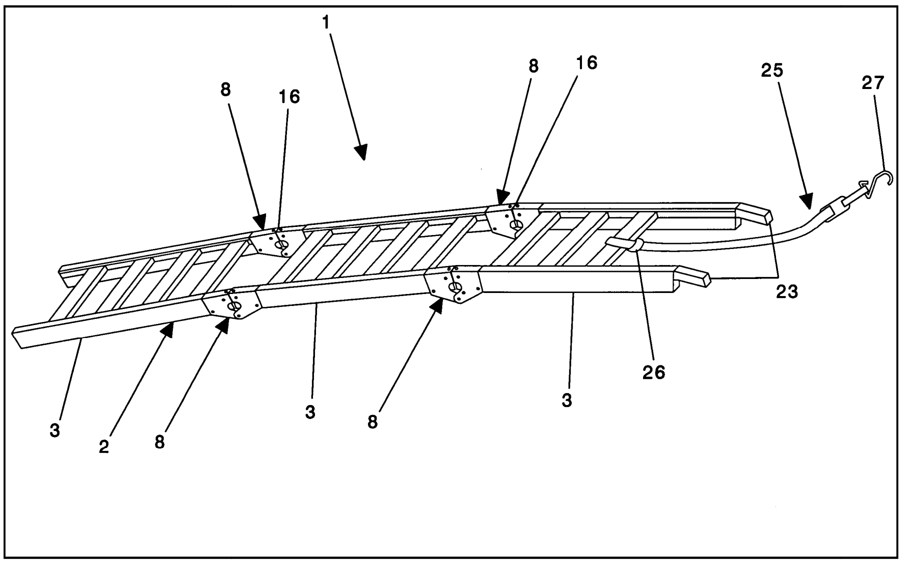


Figure 1: Jerry P. Lensing's Tri-Folding Ramp

The ramp will need to support the weight of the heaviest dirt bikes. Research was done on weights of several types of dirt bikes with engines over 250 cubic centimeter (cc) engines. Dirt bikes with smaller engines were disregarded due to their lighter engines. Weights were taken from manuals provided by the manufacturer of Honda, Suzuki, Kawasaki and KTM, and are shown in Figure 2. The Suzuki DR650SE had the heaviest weight of 366 lbs.

Table 1: Weights of Large Dirt Bikes

Weights of Large Dirt Bikes (over 250cc engines)							
Make	Honda				Suzuki		
Model	CRF450X	CRF450R	CRF250X	XR650L	DR650SE	DR-Z400S	RM-Z450
Weight (lbs.)	262	242.7	254	346	366	321	249

Make	Kawasaki		KTM		
Model	KX450F	KX250F	500 XC-W	450 SX-F	350 SX-F
Weight (lbs.)	248	233.6	245	236.6	231.3

Due to the design needing to be easily transported and set up by a single individual, as well as have the strength to support a vehicle as a strip and a dirt bike as a ramp, 6061-T6 Aluminum will be used. T6 temper 6061 has an ultimate tensile strength of at least 42,000, and yields strength of at least 35,000 psi. (MatWeb)

Table 2: Wheelbase Lengths of Light Utility Trucks

	Wheelbase Lengths for Various Light Utility Trucks								
Make/Model	Ford Ranger			Chevrolet Colorado			Toyota Tacoma		
Series	Compact	Extended Cab	Crew Cab	Regular Cab	Extended Cab	Crew Cab	Regular Cab	Access Cab	Double Cab
Wheelbase (inches)	111.6	117.6	125.9	111.2	126	120	109.4	127.4	127.4
Wheelbase (feet)	9.3	9.8	10.5	9.3	10.5	10.0	9.1	10.6	10.6

Make/Model	Dodge Dakota		Nissan Frontier			
Series	Regular Short Bed	Regular Long Bed	Regular Cab	King Cab	Crew Cab Short Bed	Crew Cab Long Bed
Wheelbase (inches)	111.9	123.9	104.3	116.1	116.1	131.1
Wheelbase (feet)	9.3	10.3	8.7	9.7	9.7	10.9

In order for the ramp to double as a traction pad, it must not exceed the length of the shortest wheelbase of a light utility truck. An investigation was done on the different wheelbase lengths of many light utility trucks and the results found that the shortest wheelbase was the Nissan Frontier Regular Cab, having a wheelbase of 104.3 inches, or 8.7 feet. Therefore the ramp must not exceed 8.6 feet in length.

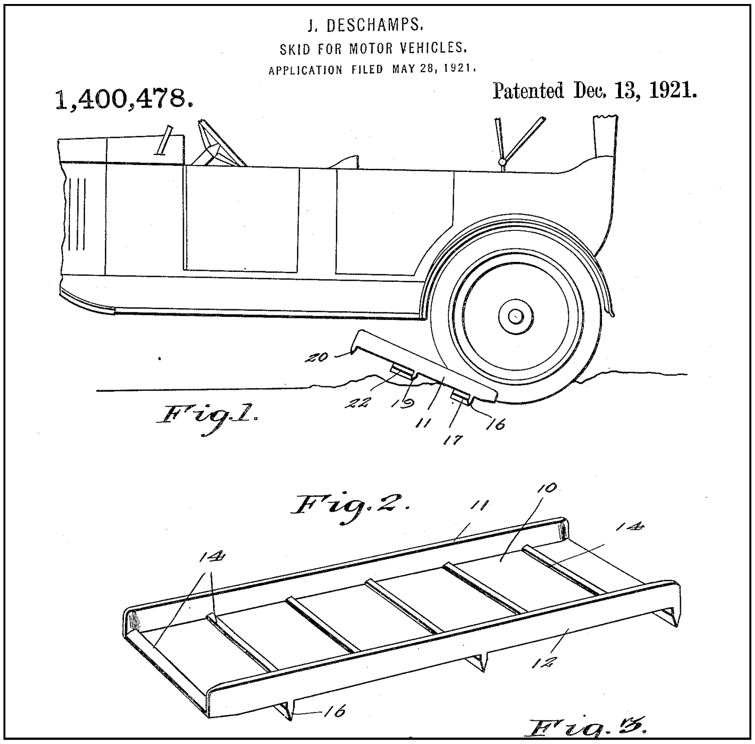


Figure 2: Joseph Deschamps' Skid for Motor-Vehicles

Joseph Deschamps' design of a small and durable skid that provides a way for motor vehicles to be driven our of a deep rut in soft earth without the necessity of employing jacks, tension chains, or a winch. This is a simple and easy design, which implies the use of spikes or cleats to grip the earth as well as the tire in order to drive the vehicle out of a rut or soft earth. This design will be taken into account during the design phase to ensure traction will be given to the tire.

PROCEDURES AND METHODS

Design Procedure

SolidWorks was used for the entire design of the Utility Strip. It was chosen due to its ability to create 3-D designs as well as perform a stress analysis of different members.

Utility Strip Design

The ramp was designed primarily to be able to withstand the weight of the heaviest of dirt bikes as a ramp, and the weight of a truck as a traction strip. Research was conducted on the different weights of dirt bikes and the material used by pre-existing motorcycle ramps. 6061-T6 aluminum was chosen for the material due to its high strength and lightweight. The one-foot width of the ramp was chosen with a consideration to the width of the common truck tire. This would give the truck's tire the maximum surface area it will need to get itself out of soft terrain or a rut.

The aluminum rectangular tubing that was chosen was a 1 x 2"x 1/8" which was thicker than regular motorcycle ramps because of the strength needed to support a trucks tire. The 3/8" aluminum round was used as traction on the top of the ramp as well as a smoother surface for a dirt bike to be able to roll up and down with ease. The 1 ½ x 1 ½ x 1/4" aluminum angle was chosen to be attached to the bottom of the strip to give the strip a non-slip surface to hold and grip the surface of the soft material under the tire. A completed design of the ramp can be seen below in Figure 5.

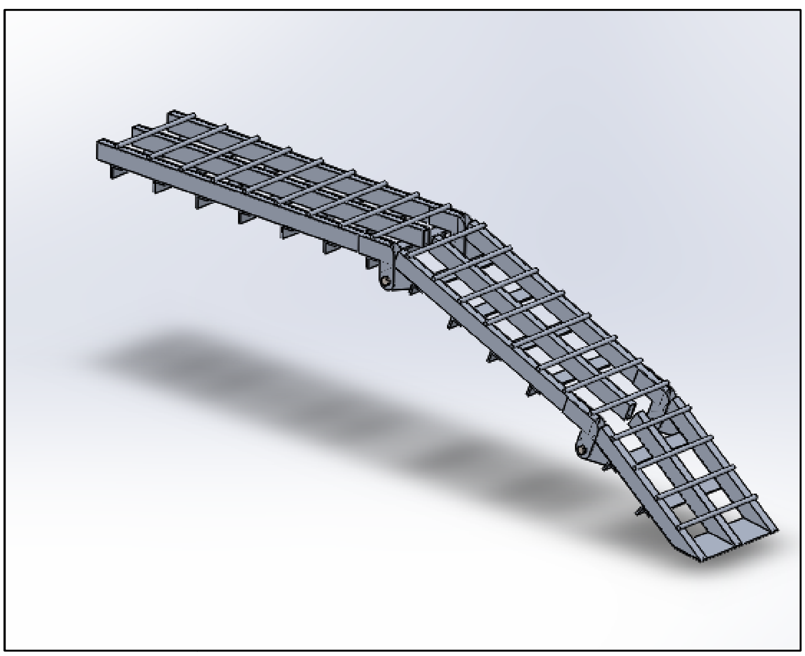


Figure 3: SolidWorks Design

The design of the ramp is in three folding sections. This was to allow the flexibility of the shortest section to be wedged under a tire to be able to regain traction of a dug in truck tire. The remaining sections will be to lay somewhat flush with the contour of the ground surface in order to get momentum for the truck to completely drive out of its previously stuck position.

Hinge Design: The hinges on the ramp were designed to allow a 180-degree rotation of the ramp in order to be folded in half for storage and transportation as well as giving the angle iron the clearance it needs to be properly folded. The rails of the ramp will act as a stop in order for it to lock into a flat position to be used as a ramp for the loading and unloading of a dirt bike into the bed of the truck. These hinges can be seen below in Figure 6.

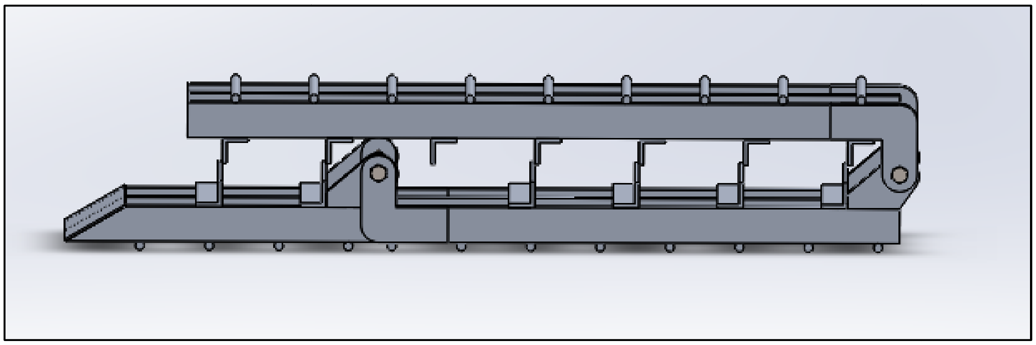


Figure 4: Folded Utility Strip Design

Analysis Procedure

An analysis was done on the total weight, cost, and strength of the material.

Weight: The total weight of the utility strip needed to be light enough for a single person to easily maneuver. The estimated weight of the entire utility strip is estimated in the *Analysis* Section and it will be estimated to weigh no more than 50 lbs. At this weight it should be light enough for the user to easily maneuver.

Cost: A cost analysis was made of the utility strip was obtained by the use of a cut list and a bill of materials. This was done in Microsoft Excel with the estimated prices of the materials from B&B Steel in Santa Maria, CA. All materials were ordered with excess length in order to account for materials lost in cutting and if mistakes were made in the fabricating process. The common stick lengths of the Aluminum rectangular tubing were 20 feet, the aluminum round was 12 feet, and the aluminum angle was 25 feet. To keep costs lower, however, one stick of rectangular tubing was cut at B&B Steel into an 8-foot section. The lengths of the sticks were multiplied by the price per stick to obtain the total price. The subtotal of the prices of materials was then multiplied by the sales tax, and then again by 10% to account for other consumables (shielding gas, welding rod, etc.)

The cost of labor was estimated from the rate of local shops, which was $80. The labor was expected to be completed by a single highly experienced individual. Labor was completed in steps to improve efficiency by breaking up tasks that included cutting, prepping, and welding the material.

The goal of the Utility Strip is to compete with the already existing folding motorcycle ramps which can sell anywhere for $70 to $150 for the higher end ramps, as well as existing traction strips sell anywhere from $40 to $130. The utility strip however would be more appealing to the user because of its second function. But because of the utility of this ramp being traction strip as well as a ramp the ideal selling price would be $200.

Strength: The strength of the utility strip will be calculated for two different situations. First it will need to support the weight of a dirt bike being rolled up and into the bed of a truck. This will be calculated using the long hand procedure using the equation for a simple beam with a concentrated load at the center. The supports will be the ground and the tailgate of the truck. The second situation is when the wheel of the truck is rolling over the strip while being uniformly supported by the soil where it is placed.

Solid Works will also be used to analyze these situations for the largest section of the ramp. This section will be the most likely to fail because of the length of it.

Fabrication Procedure

When all the materials were obtained, they were cut down to their specific lengths. The rectangular tubing was cut down into three 4-foot sections, three 2-½ ft. sections, and three 1-½ foot sections. Next the round and the angle was cut into one-foot sections. After the cutting process, the burs were removed using a belt sander.

Next the rectangular tubing was placed on a welding table, squared up, and prepped for welding. The aluminum needed to be cleaned thoroughly before welding to remove any impurities that could weaken the weld. A clean wire brush was used before Scotch Brite to ensure proper cleaning. TIG (Tungsten Inert Gas) welding with a 3/32" and 1/8" 4043 aluminum welding rod was used.

First, the round was attached to the top of the tubing with small welds on both sides of the round to ensure it would hold in stress situations both directions, shown in Figure 5. This process of welding the rods was done for each of the three sections.

Next, the angle was placed on the bottom side of the tubing to act as the "cleats" of the strip. Both sides of the angle were welded to the tubing as well to ensure a proper hold. The angles were placed on the smallest section with a 6-inch spacing between each other in order to support the tubing as well as provide multiple surfaces for traction with the ground. Figure 8 shows how these angles were placed.

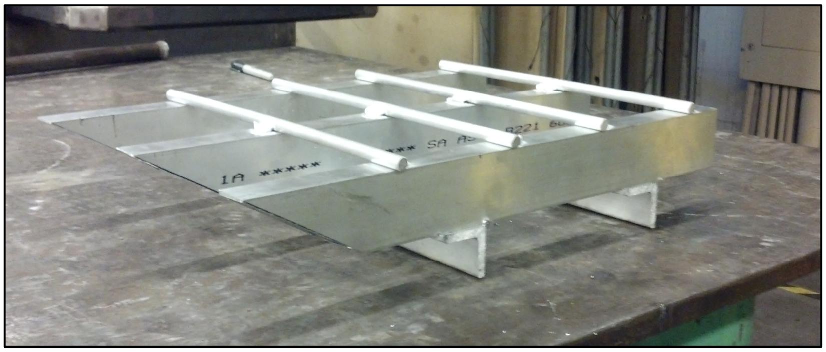


Figure 5: Angles and Rod Attached to Tubing

Finally, the hinges were cut out of 10-gauge aluminum sheet using the CNC Plasma Cutter. The design of the outer and inner hinges were created using AutoCAD and then transferred to the Plasma cutter. The hinges were then clamped to the rectangular tubing using a set of clamps to ensure the aluminum would not warp when welded. The hinges were then welded and aligned for proper function.

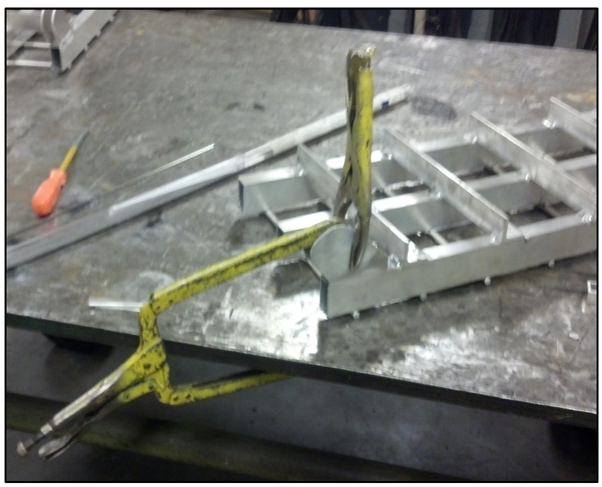


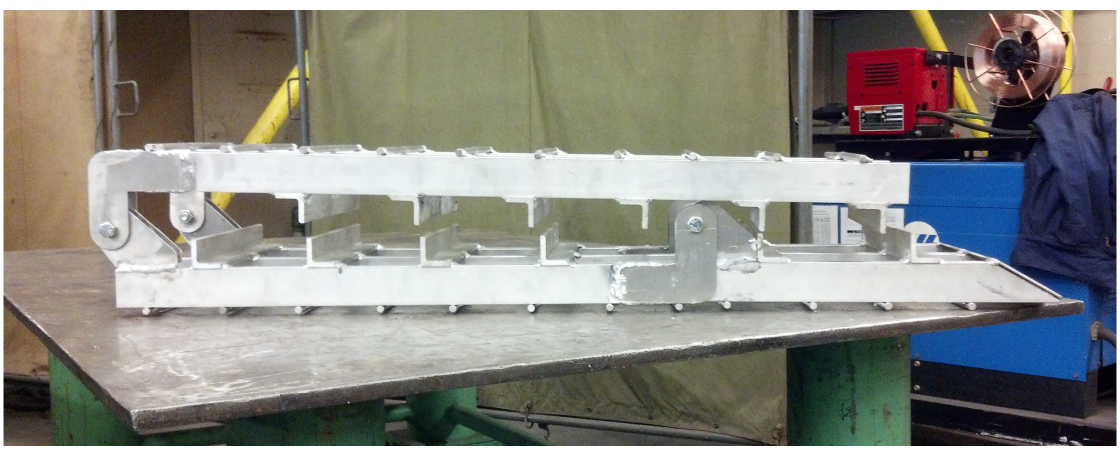
Figure 6: Clamped Hinges

The holes for the hinge bolt was then drilled using a ½ inch hole. In between the hinges a small plastic spacer was cut and placed to keep the hinge aligned with itself and to keep the aluminum from binding with each other.

Figure 7: Completed Hinges

A 10-gauge aluminum plate was attached to the foot of the strip in order to lay flush with the ground as a ramp. This will also enable the strip to be easily wedged under the tire of a truck.

Figure 8: Completed Utility Strip Folded



Testing Procedure: The testing procedure will be to put the utility strip to use in a real life situation. To test the strength of the utility strip as a ramp, a 2001 Honda XR400R will be used as a test bike to be loaded into the bed of a 2001 Ford Ranger. The Ford Ranger will also be brought to the sand dunes in Pismo Beach, CA, and have the rear tire dug into the ground and test the utility strip and its ability to regain traction to the tire.

RESULTS

Weight: The completed Utility Strip weights approximately 35lbs. This weight is easily picked up, folded, and maneuvered by an individual.

Cost: The tables below show the cost of materials as well as the cost of labor for creating the Utility Strip. The total Cost of the Utility Strip was $202.49 for materials (Table 1), and $305.33 for labor (Table 2), bringing the total cost to $507.82.

Table 3: Cut List and Bill of Materials

	Cut List			Bill of Materials		
	Length (in)	Quantity	Total (ft)	Sticks	Price/Foot	Total
Material						
1 x 2 x .125" Rectangular Tubing	48	3	12			
1 x 2 x .125" Rectangular Tubing	30	3	7.5			
1 x 2 x .125" Rectangular Tubing	18	3	4.5			
Total			**24**	**1.5**	**$ 3.80**	**$ 92.60**
.375" Round	12	10	10			
.375" Round	12	8	8			
.375" Round	12	4	4			
Total			**22**	**2**	**$ 0.68**	**$ 15.00**
1 1/2 x 1 1/2 x .25" Angle	12	2	2			
1 1/2 x 1 1/2 x .25" Angle	12	4	4			
1 1/2 x 1 1/2 x .25" Angle	12	6	6			
Total			**12**	**1**	**$ 2.56**	**$ 64.00**
				Sub Total		$ 171.60
				Sales Tax	8%	$ 13.73
				Consumables	10%	$ 17.16
				Total Cost		**$ 202.49**

Table 4: Cost of Labor

Cost of Labor					
Task	Time (min)	Quantity	Unit	Total Time (hours)	Cost
Cutting	1	46	cuts	0.77	$ 61.33
Section Layout	10	3	sections	0.50	$ 40.00
Cleaning	2	38	pieces	1.27	$101.33
Welding	0.5	154	welds	1.28	$102.67
				Total Cost	$ 305.33

Note that the costs of labor are estimated using skilled labor pricing and the times to complete the tasks are also those of a skilled worker.

Strength: The strength of the utility strip was tested and passed both load situations.

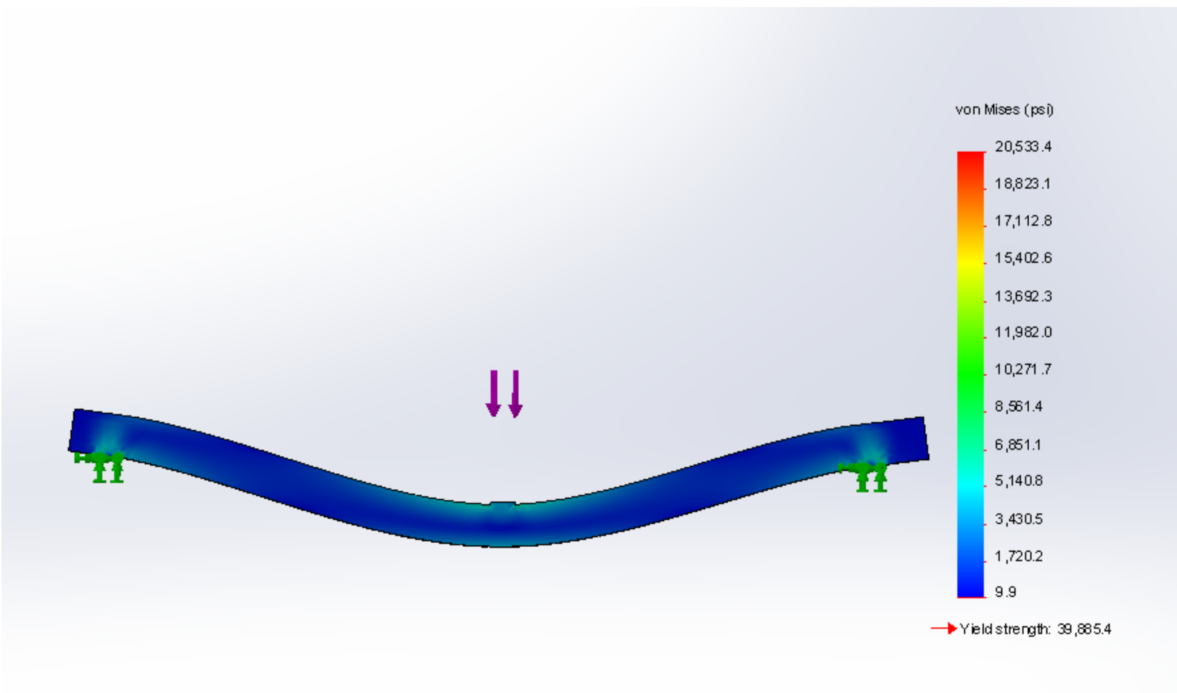


Figure 9: Stress Analysis of Longest Tubing

By using the Simulation feature in SolidWorks, a load was placed in the center of the longest tubing, and a load of 366 lbs. was placed on it. This is the weight of the Suzuki DR650SE. One can see that this beam can easily support the weight of it. Not taken account of in Figure 10 is that there will be three beams that will all act together to support the weight of the dirt bike. I overdesigned this in order to support the weight of a truck driving over it as well as a fraction of the load being transferred to the hinges.

Testing: Testing of the Utility Strip was performed and was successful for both loading situations. Shown below in Figure 11 is a motorcycle successfully being loaded into the bed of a truck.

Figure 10: Use as a Ramp

Next the ramp was used to regain traction to a "dug in" tire in sand. The smallest section of the ramp was wedged under the tire while laying flat with the contour of the land. The truck was then able to regain traction and drive out of its previously stuck position. Shown below is the truck stuck in the sand with the utility strip properly being used.

Figure 11: Utility Strip Wedged Under Tire

Figure 12: Regaining Traction

Figure 13: Regained Traction

The utility strip was tested numerous times to regain traction, and was successful. The use of this strip eliminated the need of a winch or another vehicle to pull the truck from its previously stuck position.

DISCUSSION

The total cost of materials and labor for the Utility Strip is very high compared to the motorcycle ramps and traction pads that are on the market today. That is due to the material not being ordered in bulk, and the labor that was being done on it being a highly skilled worker. If the materials were ordered in bulk and the labor was done at a more effective rate, then the cost of producing the Utility Strip would cost much less to produce, therefore being much cheaper for the consumer.

When looking at the materials that were ordered, the angle iron was the thicker than the rectangular tubing that it was attached to. This added to the total weight as well as the price of the material. If a 1/8" thickness were used instead of the 1/4" thickness, it would have dropped the total cost as well as the weight. The thickness of the rectangular tubing could have been thinner as well. When looking at the safety factor for the tubing being 2.37 (Appendix B), this is very high because of the added support of the angles and rod. A thinner material could have been used which would drop the cost as well as the weight. A larger material was chosen to strengthen it as well as easier to weld.

After reviewing the cost of labor (Table 4) the most hours were spent on welding the material. More time was spent on welding the angle iron to the tubing because of the six individual welds that were put on each angle. The time could be cut in half for these welds if the same technique of only three welds that was used to weld the round to the tubing were used for welding the angle. By saving time on welding, the fabricating costs would drop significantly, making a cheaper more desirable product for the consumer.

A significant amount of time was spent during the cleaning phase before welding each part together. This could all be done in one time using Acetone instead of Scotch Brite and a wire brush. This would increase efficiency of cleaning and the welding could all be done at one time. These two changes with regards to cleaning and welding are shown below in Table 5.

Table 5: Revised Cost of Labor

Cost of Labor					
Task	**Time (min)**	**Quantity**	**Unit**	**Total Time (hours)**	**Cost**
Cutting	1	46	cuts	0.77	$ 61.33
Section Layout	10	3	sections	0.50	$ 40.00
Cleaning	1	38	pieces	0.63	$ 50.67
Welding	0.25	154	welds	0.64	$ 51.33
				Total Cost	**$ 203.33**

RECCOMENDATIONS

After the utility strip was completely constructed and tested, it seemed that the materials used could have had thinner wall thicknesses. By reducing the thickness, it would allow for cheaper cost and lighter weight.

When using the utility strip as a ramp for a motorcycle, a tie down should be placed from the ramp to the hitch of the truck to ensure that it does not slip from side to side when the motorcycle is being pushed up. This recommendation can be seen in Figure 9.

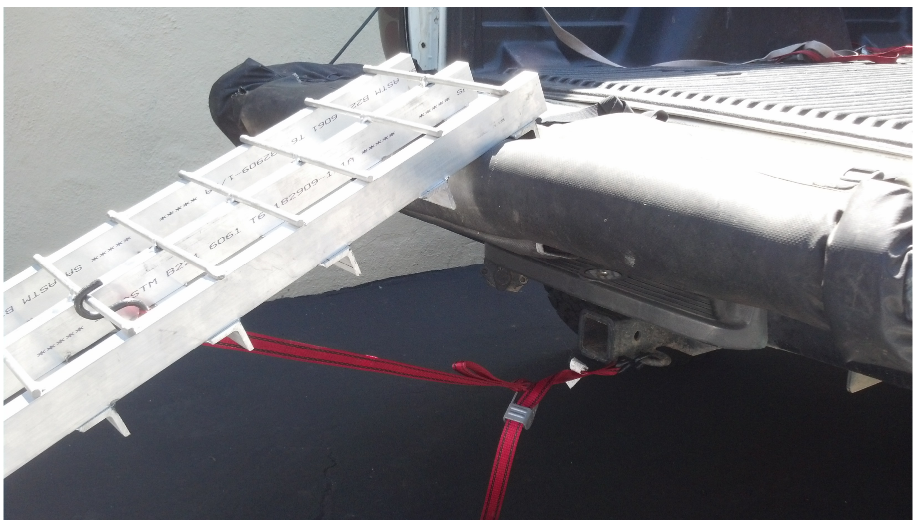


Figure 14: Tie Down Support

The hinge design worked very well for what it was designed to do. However, it should only be used for a traction strip on softer soil surfaces. The hinges have a taller height than the angle iron, which places a large load on the hinges if used on a flat hard surface that could cause the hinges to fail.

Labor costs are high in the US, and it would be much cheaper to have the labor done elsewhere which would drop the price of it significantly. Be sure that the laborer is very experienced at TIG welding, the thinner the material is, the easier it is to burn though it.

A second Utility Strip could be used to wedge under the other drive wheel of a truck to ensure equal traction to both wheels, however with a two wheel drive truck without a rear differential lock, the use of only one Utility Strip was sufficient.

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APPENDIX A:

HOW PROJECT MEETS REQUIREMENTS FOR ASM MAJOR

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ASM Project Requirements

The ASM senior project must include a problem solving experience that incorporates the application of technology and the organizational skills of business and management, and quantitative, analytical problem solving.

Application of Agricultural Technology. The project will involve fabrication technologies as well as the need for a device to provide traction to trucks in loose terrain as well as loading and unloading vehicles from truck beds.

Quantitative, Analytical Problem Solving. Quantitative problem solving will include the cost analysis and the bending stress calculations.

Application of Business and/or Management Skills. The project will involve business/management skills in the areas of cost and productivity analyses, and labor considerations.

Capstone Project Experience

The ASM senior project must incorporate knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge/skills from the following courses.

- BRAE 129 Lab Skills/Safety
- BRAE 133 Engineering Graphics
- BRAE 152 SolidWorks
- BRAE 203 Ag Systems Analysis
- BRAE 321 Ag Safety
- BRAE 342 Ag Materials
- BRAE 343 Mechanical Systems Analysis
- 418/419 Ag Systems Management

ASM Approach

Agricultural Systems Management involves the development of solutions to technological, business or management problems associated with agricultural or related industries. A systems approach, interdisciplinary experience, and agricultural training in specialized areas are common features of this type of problem solving.

Systems Approach. The project involves the integration of multiple functions (strength, flexibility, and traction), to provide a solution to two problems that often come together.

Interdisciplinary Features. The project touches on aspects of strength and materials, financial analysis, fabrication skills and agricultural safety.

Specialized Agricultural Knowledge. The project applies specialized knowledge in the areas of mechanical and fabrication systems, and agricultural safety

APPENDIX B:

DESIGN CALCULATIONS

Properties of Geometric Shapes method for finding S:

$$S = \frac{bd^3 - b_1 {d_1}^3}{6d} = \frac{(1in)(2in)^3 - (0.75in)(1.75in)^3}{6(2in)} = .332\ in^3$$

Calculating Mas Moment:

$$M_{max} = P\ell = 366\ lbs * 41\ inches = 15{,}006\ inch - lbs$$

Calculating Required S:

$$S_{required} = \frac{M_{max}}{F_y} = \frac{\frac{15{,}006 in - lbs}{3\ rails}}{35{,}000 psi} = .14 in^3\ per\ rail$$

Calculating Safety Factor:

$$Yeilding\ Safety\ Factor = \frac{S_{Actual}}{S_{required}} = \frac{.332\ in^3}{.14 in^3} = 2.37$$

APPENDIX C:

CONSTRUCTION DRAWINGS

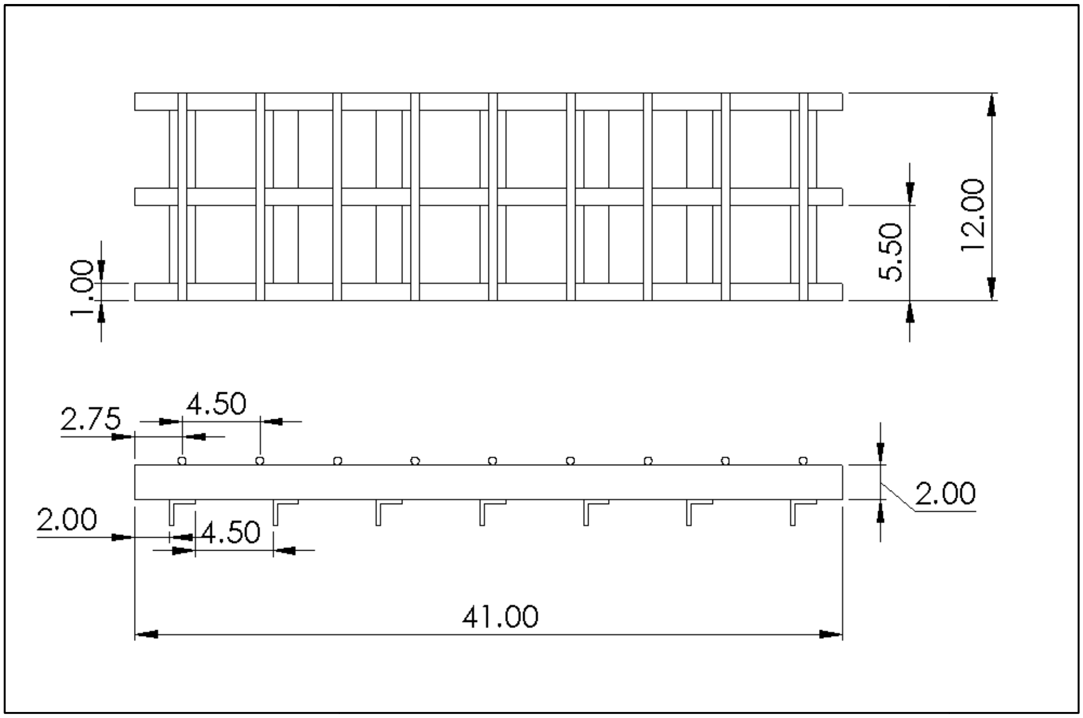

Figure 14: Large Section Layout

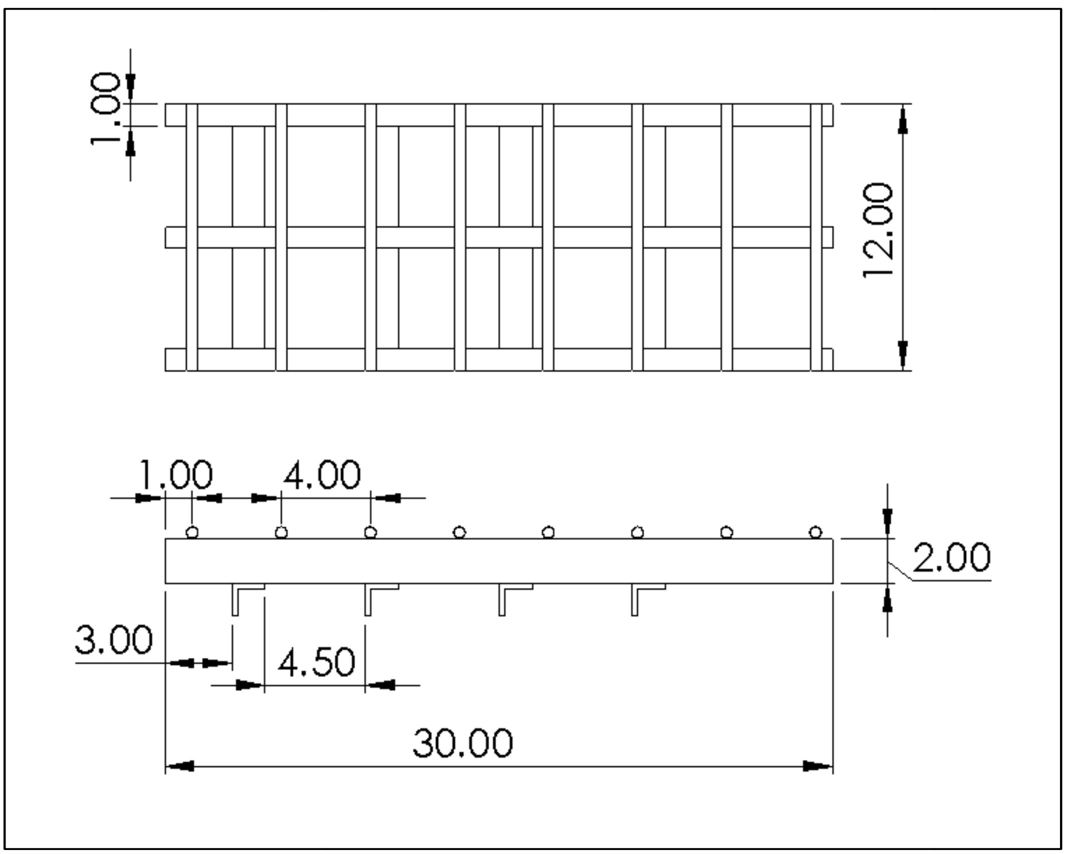

Figure 15: Medium Section Layout

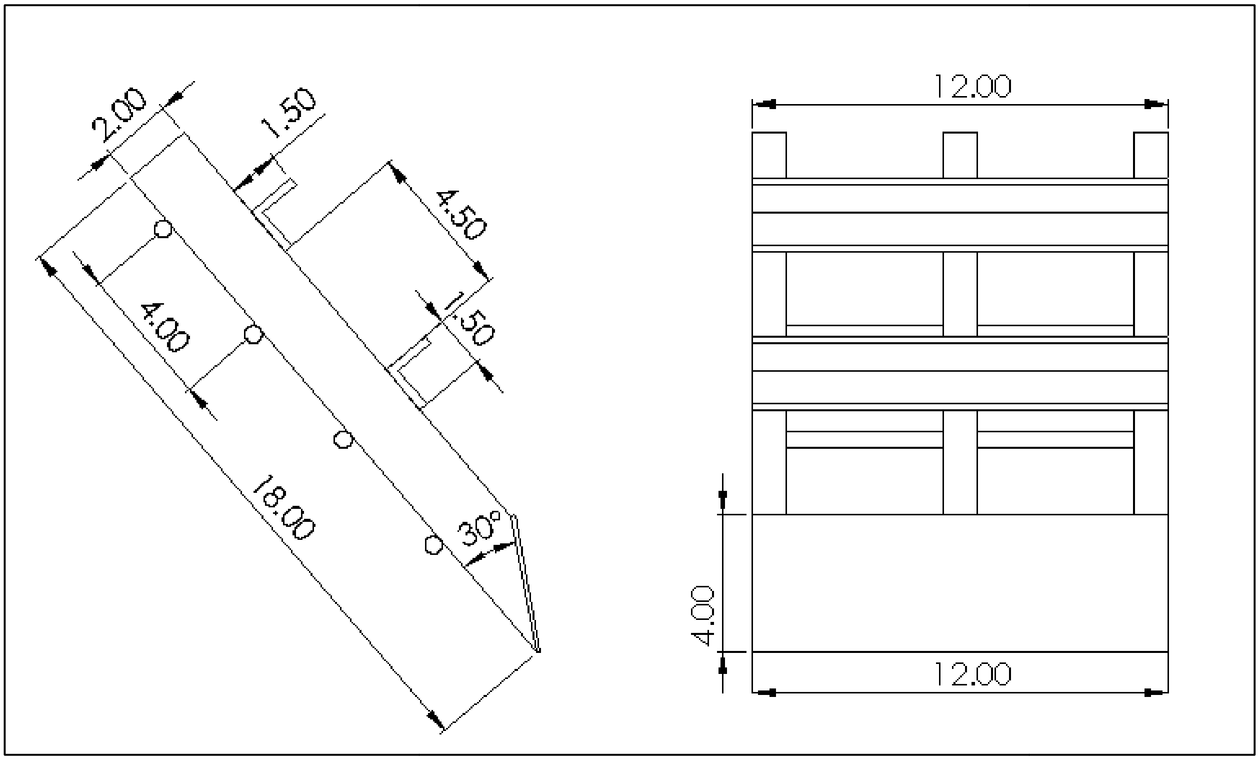

Figure 16: Small Section Layout

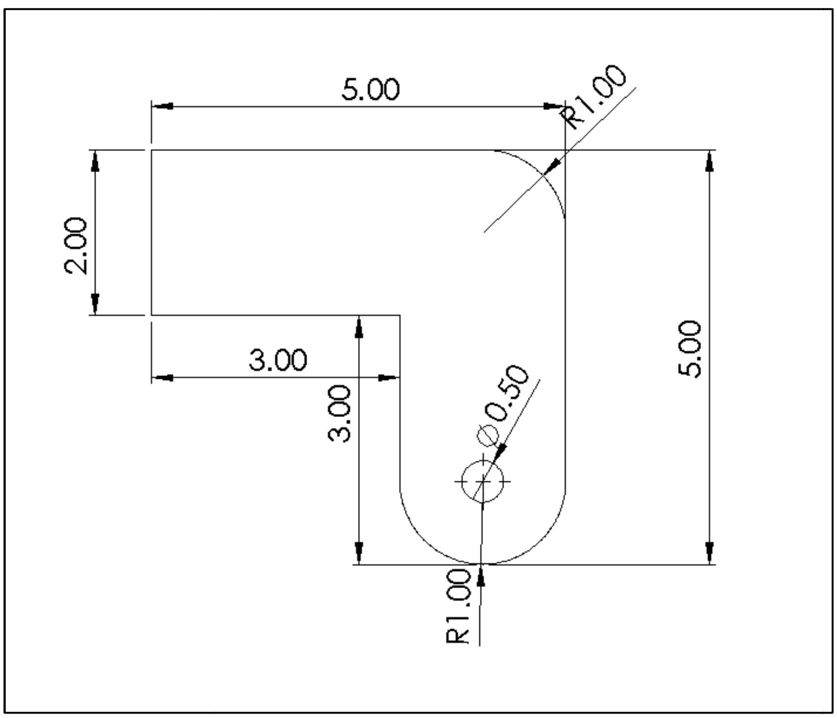

Figure 17: Outside Hinge Layout

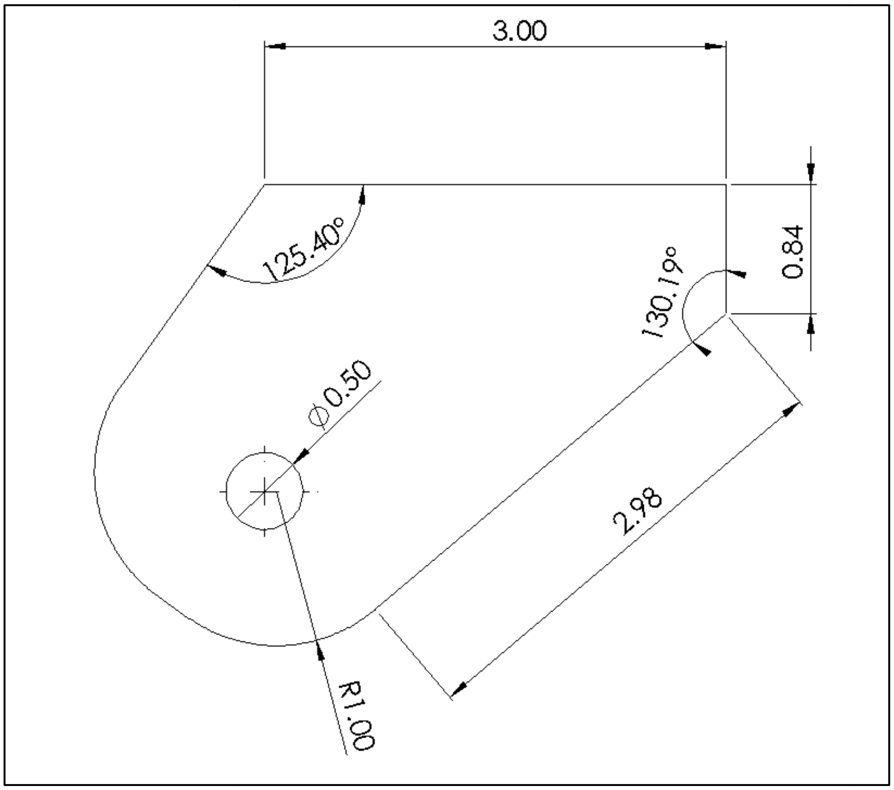

Figure 18: Inside Hinge Layout